

1 **WHAT IS CLAIMED IS:**

2 1. A compact fuel processor for converting a hydrocarbon fuel feed into a
3 purified hydrogen rich gas, comprising:

4 a reforming stack for converting the hydrocarbon fuel feed into a hydrogen rich
5 gas; and

6 a purification stack for producing the hydrogen rich gas suitable for direct feed to
7 a fuel cell.
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9 2. The compact fuel processor of claim 1, wherein the reforming stack
10 includes a first plurality of cylindrical vessels, wherein the first plurality of cylindrical
11 vessels are stackable without the need for connecting piping between each vessel; and
12 wherein the purification stack includes a second plurality of cylindrical vessels, wherein
13 the plurality of cylindrical vessels are stackable without the need for connecting piping
14 between each vessel.
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16 3. The compact fuel processor of claim 2, wherein the reforming stack is
17 aligned vertically.
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19 4. The compact fuel processor of claim 1, wherein the reforming stack
20 comprises a shift vessel, an autothermal reforming vessel, and an anode tail gas oxidation
21 vessel; and wherein the purification stack comprises a preferred oxidation vessel, a first
22 desulfurization vessel, and a second desulfurization vessel.
23

24 5. The compact fuel processor of claim 4, wherein the hydrocarbon fuel feed
25 is sequentially introduced to:

26 first, to the anode tail gas oxidation vessel to produce a preheated hydrocarbon
27 fuel feed;

28 second, to the first desulfurization vessel to produce a desulfurized hydrocarbon
29 fuel feed;

30 third, to the autothermal reforming vessel to produce a first intermediate hydrogen
31 stream;

1 fourth, to the second desulfurization vessel to produce a desulfurized intermediate
2 hydrogen stream;

3 fifth, to the shift vessel to produce a second intermediate hydrogen stream; and

4 sixth, to the preferential oxidation vessel to produce the hydrogen rich gas.

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6 6. The compact fuel processor of claim 5, wherein the anode tail gas
7 oxidation vessel comprises:

8 an oxidation core containing a water gas shift catalyst for oxidizing fuel cell
9 anode tail gas to produce a hot exhaust gas; and

10 a first finned section having a plurality of external vertical fins surrounding the
11 oxidation core for dissipating the heat of reaction produced within the oxidation core;

12 wherein the hydrocarbon fuel feed is introduced to the first finned section to
13 produce the preheated hydrocarbon fuel feed.

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15 7. The compact fuel processor of claim 6, further comprising a heat
16 exchanger for heating water with the hot exhaust gas to produce a preheated water
17 stream.

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19 8. The compact fuel processor of claim 5, wherein the autothermal reforming
20 vessel comprises:

21 a reforming core containing an autothermal reforming catalyst for reacting the
22 desulfurized hydrocarbon fuel feed, the preheated water stream, and air to produce the
23 first intermediate hydrogen stream; and

24 a spiral exchanger section surrounding the reforming core;

25 wherein the spiral exchanger section contains two channels for preheating the
26 desulfurized hydrocarbon fuel feed with the first intermediate hydrogen stream.

27
28 9. The compact fuel processor of claim 5, wherein the shift reactor vessel
29 comprises:

1 a shift core containing a water gas shift catalyst for reacting the desulfurized
2 intermediate hydrogen stream and water to produce the second intermediate hydrogen
3 stream; and

4 a second finned section having a plurality of external vertical fins surrounding the
5 shift core for dissipating the heat of reaction produced in the shift core;

6 wherein the desulfurized intermediate hydrogen stream is preheated in the second
7 finned section prior to being introduced to the shift core.

8
9 10. The compact fuel processor of claim 5, wherein the first desulfurization
10 vessel comprises a desulfurization catalyst bed for substantially desulfurizing the
11 preheated hydrocarbon fuel feed to produce a desulfurized hydrocarbon fuel feed.

12
13 11. The compact fuel processor of claim 5, wherein the second desulfurization
14 vessel comprises a desulfurization catalyst bed for substantially desulfurizing the first
15 intermediate hydrogen stream to produce a desulfurized intermediate hydrogen stream.

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17 12. The compact fuel processor of claim 5, wherein the preferred oxidation
18 vessel comprises:

19 a preferred oxidation catalyst bed for reacting air and the second intermediate
20 hydrogen stream to produce the hydrogen rich gas; and

21 a heat exchange chamber for cooling the hydrogen rich gas with water in a
22 cooling coil

23
24 13. A compact fuel processor for converting a hydrocarbon fuel feed into
25 hydrogen rich gas, comprising:

26 a reforming module for converting the hydrocarbon fuel feed into the hydrogen
27 rich gas, wherein the hydrogen rich gas is suitable for direct feed to a fuel cell; and

28 an oxidizing module for oxidizing fuel cell anode tail gas to produce a hot exhaust
29 gas, wherein the hot exhaust preheats the hydrocarbon fuel feed to the reforming module.

14. The compact fuel processor of claim 13, wherein the oxidizing module comprises:

a first heat exchanger core;
an oxidation core vessel containing an oxidation catalyst; and
a first desulfurizing vessel surrounding the oxidation core vessel and forming a first annular space filled with desulfurization catalyst; and

wherein the oxidation core vessel oxidizes the fuel cell anode tail gas to produce a hot exhaust gas; and

wherein the hydrocarbon fuel feed is preheated by the hot exhaust gas in the first heat exchanger coil to produce a preheated hydrocarbon fuel feed; and

wherein the preheated hydrocarbon fuel feed is desulfurized in the first annular space to create a desulfurized hydrocarbon fuel feed.

15. The compact fuel processor of claim 14, wherein the oxidation core vessel has a first set of external vertical fins for further preheating the preheated hydrocarbon fuel feed to produce a second preheated hydrocarbon fuel feed, and wherein the second preheated hydrocarbon fuel feed becomes the hydrocarbon fuel feed introduced to the first annular space.

16. The compact fuel processor of claim 13, wherein the reforming module comprises:

a second heat exchanger coil;
a reforming core vessel containing an autothermal reforming catalyst bed;
a second desulfurizing vessel surrounding the reforming core vessel and forming a second annular space filled with desulfurization catalyst;

a shift vessel surrounding the second desulfurizing vessel and forming a third annular space filled with water gas shift catalyst; and

a preferred oxidation vessel surrounding the shift vessel and forming a fourth annular space filled with preferred oxidation catalyst; and

wherein the hydrocarbon fuel feed is preheated by the hydrogen rich gas in the second heat exchanger coil to produce a third preheated hydrocarbon fuel feed; and

1 wherein the third preheated hydrocarbon fuel feed is sequentially introduced to
2 the reforming core vessel, then to the second annular space, then to the third annular
3 space, and then to the fourth annular space to produce the hydrogen rich gas.

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5 17. The compact fuel processor of claim 16, wherein the hydrocarbon fuel
6 feed is a desulfurized hydrocarbon fuel feed.

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8 18. The compact fuel processor of claim 16, wherein the reforming core vessel
9 has a second set of external vertical fins for further preheating the third preheated
10 hydrocarbon fuel feed to produce a fourth preheated hydrocarbon fuel feed, and wherein
11 the fourth preheated hydrocarbon fuel feed becomes the hydrocarbon fuel feed introduced
12 to the reforming core vessel.

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14 19. The compact fuel processor of claim 16, wherein the third annular space
15 has a third heat exchanger coil for reaction temperature control.

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17 20. The compact fuel processor of claim 16, further comprising an electrical
18 heater for starting up the autothermal reforming catalyst bed.

19
20 21. A compact fuel processor for converting a hydrocarbon fuel feed into
21 hydrogen rich gas, comprising:

- 22 a heat exchanger coil;
- 23 a reforming core vessel containing an autothermal reforming catalyst bed;
- 24 a desulfurizing vessel surrounding the reforming core vessel and forming a first
25 annular space filled with desulfurization catalyst;
- 26 a shift vessel surrounding the desulfurizing vessel and forming a second annular
27 space filled with water gas shift catalyst; and
- 28 a preferred oxidation vessel surrounding the shift vessel and forming a third
29 annular space filled with preferred oxidation catalyst; and
- 30 wherein the hydrocarbon fuel feed is preheated by the hydrogen rich gas in the
31 heat exchanger coil to produce a preheated hydrocarbon fuel feed; and

1 wherein the preheated hydrocarbon fuel feed is sequentially introduced to the
2 reforming core vessel, then to the second annular space, then to the third annular space,
3 and then to the fourth annular space to produce the hydrogen rich gas.
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5 22. The compact fuel processor of claim 21, wherein the reforming core vessel
6 has a set of external vertical fins for further preheating the preheated hydrocarbon fuel
7 feed to produce a second preheated hydrocarbon fuel feed, and wherein the second
8 preheated hydrocarbon fuel feed becomes the preheated hydrocarbon fuel feed introduced
9 to the reforming core vessel.
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11 23. The compact fuel processor of claim 21, wherein the second annular space
12 has a second heat exchanger coil for reaction temperature control.
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14 24. The compact fuel processor of claim 21, further comprising an electrical
15 heater for starting up the autothermal reforming catalyst bed.
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